Wildfire Behavior Modeling and Emergency Preparedness at the Los Alamos National Laboratory

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Major Topics

1. Wildfire behavior modeling system was developed to address past problems.

2. The model was tested and validated to ensure its accuracy.

3. We have been using the model to enhance ongoing operations at the Laboratory.

Outline

1. Preparatory events following the Dome Fire
2. Development of a wildfire behavior modeling system
3. Demonstration of simulated wildfires
4. Sensitivity analysis and validation testing
5. Monte Carlo simulation of average expected loss to the Laboratory from wildfire
6. Current and future activities

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Figure 1. The Dome Fire; April of 1996.

Laboratory Activities and Responses to the Dome Fire

1. Initiated the systematic thinning of forests and woodlands
2. Upgraded fire roads and fire breaks
3. Formalized collaborations through the Interagency Wildfire Management Team (IWMT) and other organizations
4. Upgraded emergency response and fire suppression capabilities
5. LANL Sitewide EIS identified wildfire as the most credible and significant institutional risk
6. Initiated the development of a scientific basis for wildfire management

Scientific Basis for Wildfire Management at the Laboratory

1. Developed a physics-based wildfire behavior model
2. Upgraded the weather monitoring system
3. Evaluated fuels and fire hazards at permanent monitoring plots
4. Developed a real-time wildfire behavior and soil erosion modeling system
5. Developed wildfire and natural resources management plans

Objectives of Wildfire Behavior Model Development

1. Develop a computer algorithm for evaluating relative risks from wildfire and the potential for soil erosion

2. Evaluate the long-term expected losses to the Laboratory from wildfire and contrast selected wildfire hazard reduction treatments

3. Propose a system of optimal, cost-effective mitigation action strategies

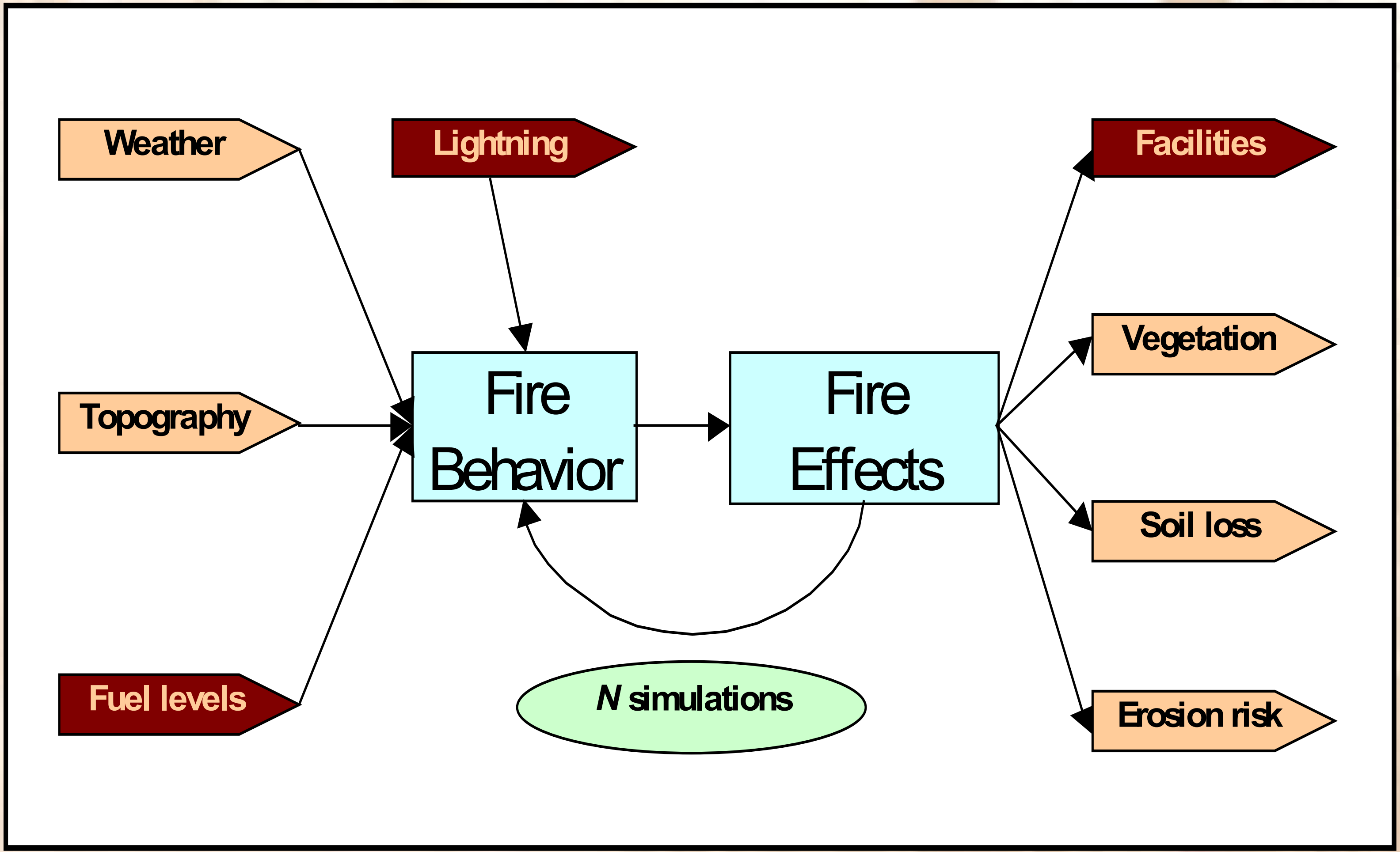

Figure 2. Design of the wildfire behavior modeling system.

Wildfire Behavior Parameters

Topography

- Slope (degrees from horizontal)
- Slope aspect (degrees from true North)
- Elevation (feet)

Wildfire Behavior Parameters

Weather

- Temperature (degrees F)
- Relative humidity (percent)
- Wind speed (miles per hour)
- Wind direction (degrees from true North)

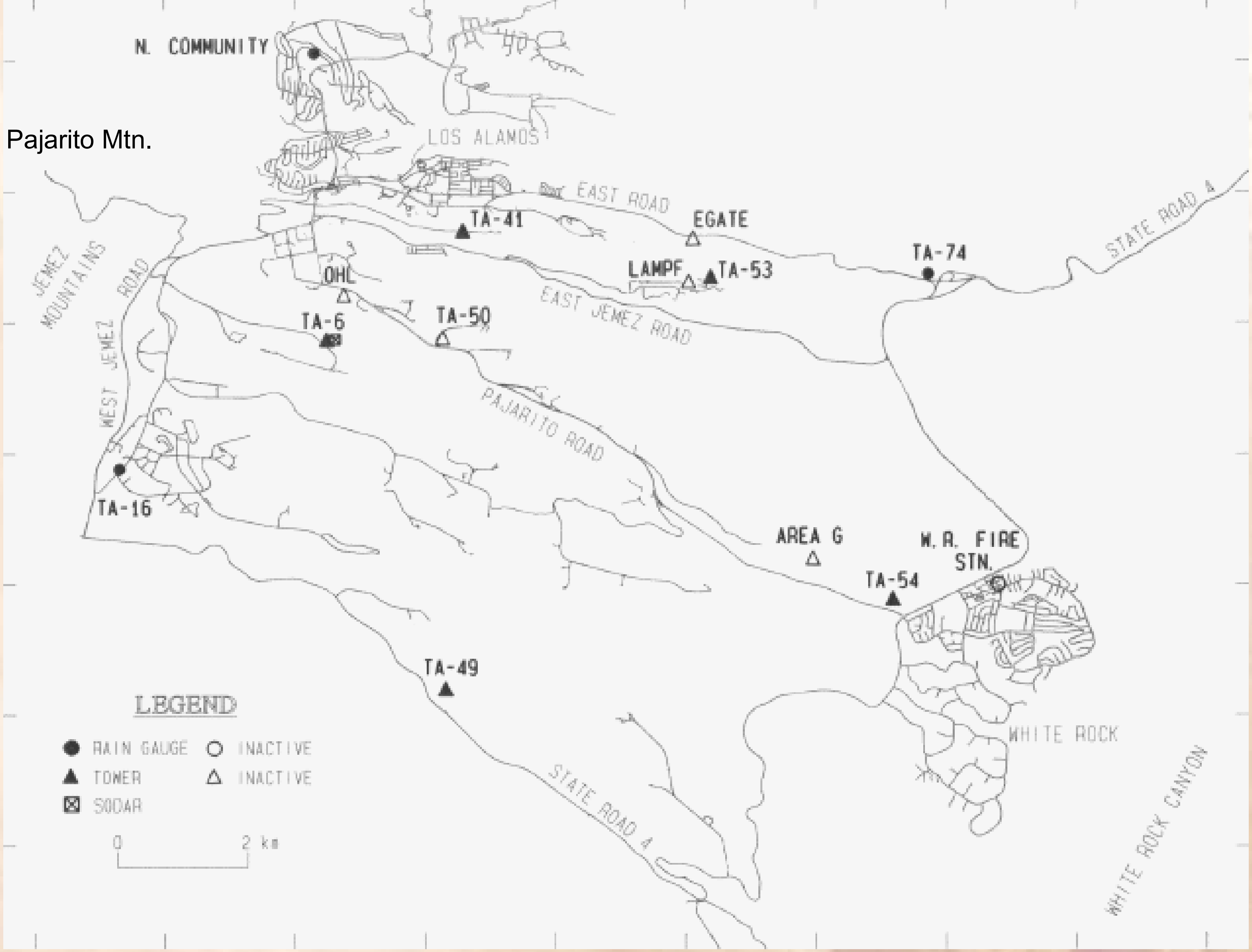

Figure 3. LANL Meteorological Stations (RRES-MAQ).

Wildfire Behavior Parameters

Sources of weather data gathered from the LANL Weather Machine

• Pajarito Mountain	10,364 ft
• TA-6	7,424 ft
• TA-49	7,045 ft
• TA-54	6,549 ft

Wildfire Behavior Parameters

Fuels

- Fuel Model (1, 2, 5, 8, 9 and 10)
- Canopy height (feet)
- Canopy cover (percent)
- Distance from shrub canopy to tree crowns (feet)
- Canopy bulk density (kg/m^3)
- Percent moisture (1-hr, 10-hr, 100-hr, live H/W)

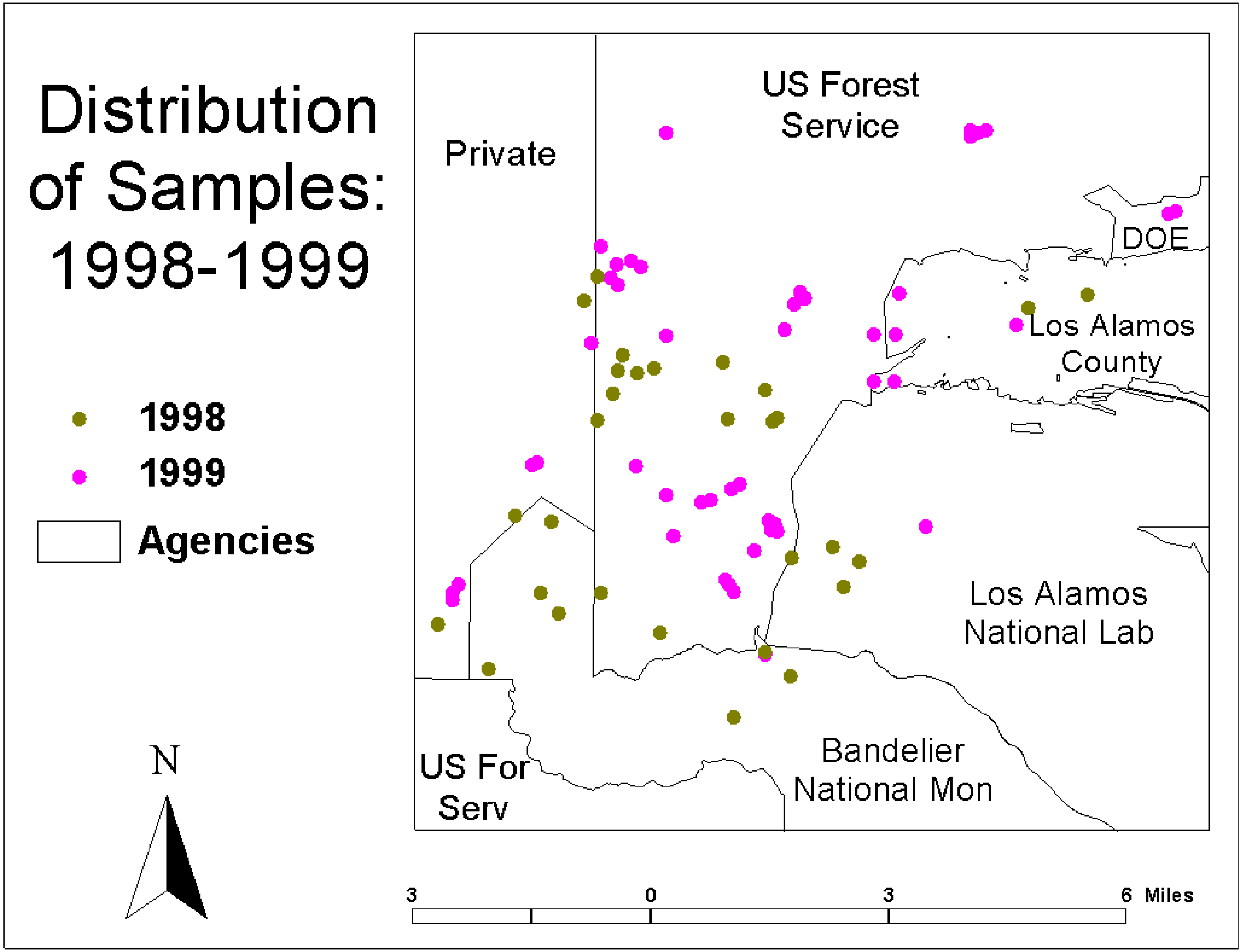

Figure 4. Permanent plots; sources of model data.

Values of Selected Parameters

Veg.	Topog.	Fuel Model	Canopy %	Canopy Ht.	Crown Ht.	Crown BD
Pine	Cyn	2	41.2	58.0	13.0	0.14
Pine	Mesa	9	64.3	56.5	19.1	0.20
Pine	Mtn	9	68.4	39.8	13.7	0.20
Conifer	Cyn	5	73.9	52.4	22.3	0.26
Conifer	Mtn	10	76.7	55.5	16.5	0.26
Spruce-Fir	Mtn	8	78.9	64.8	17.4	0.25
Aspen	Mtn	2	78.8	54.7	27.6	0.16
Grass	Mesa	2	19.1	3.3	0.7	0.09
Grass	Mtn	1	0.5	21.0	0.2	0.10

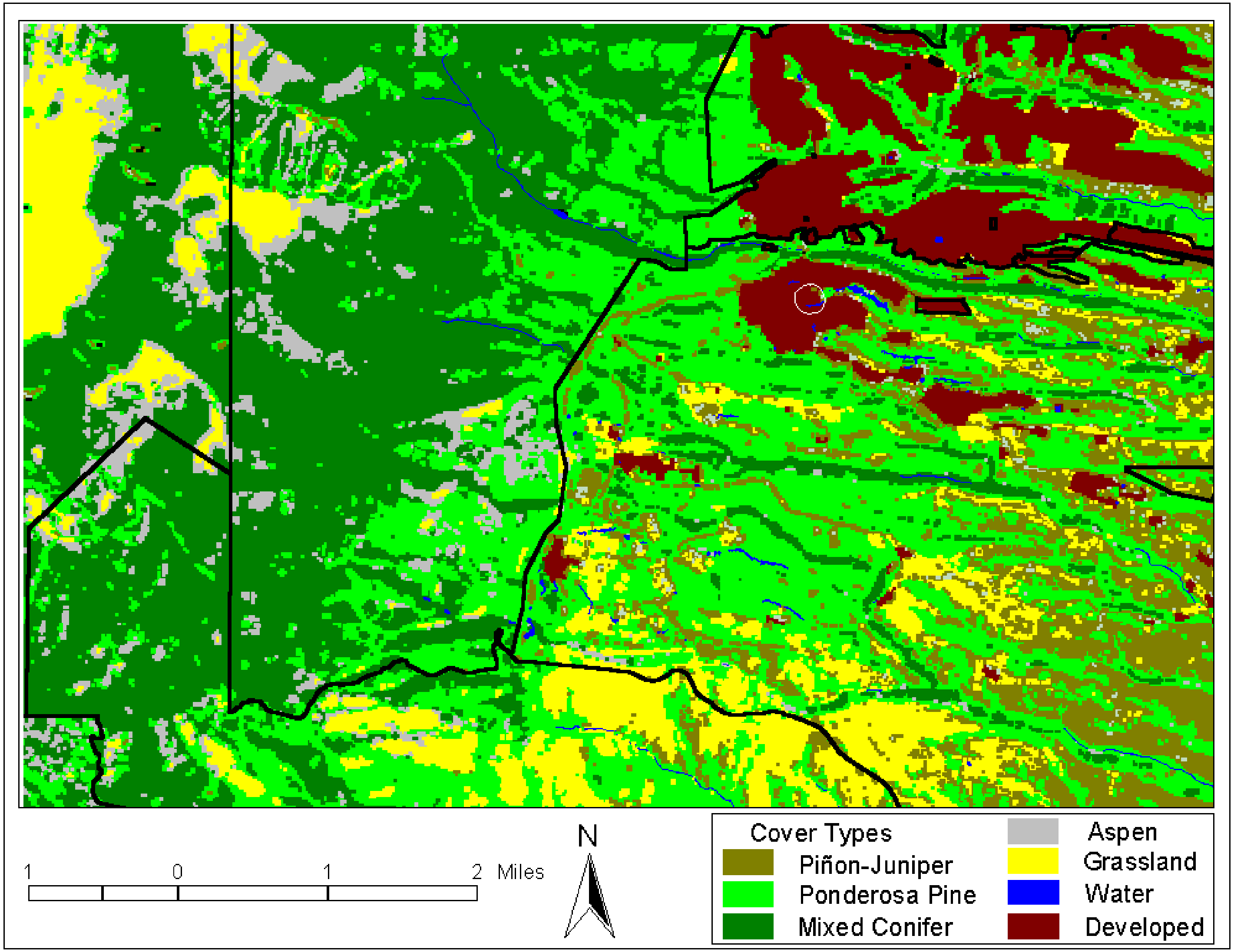

Figure 5. Vegetation map used to assign parameter values.

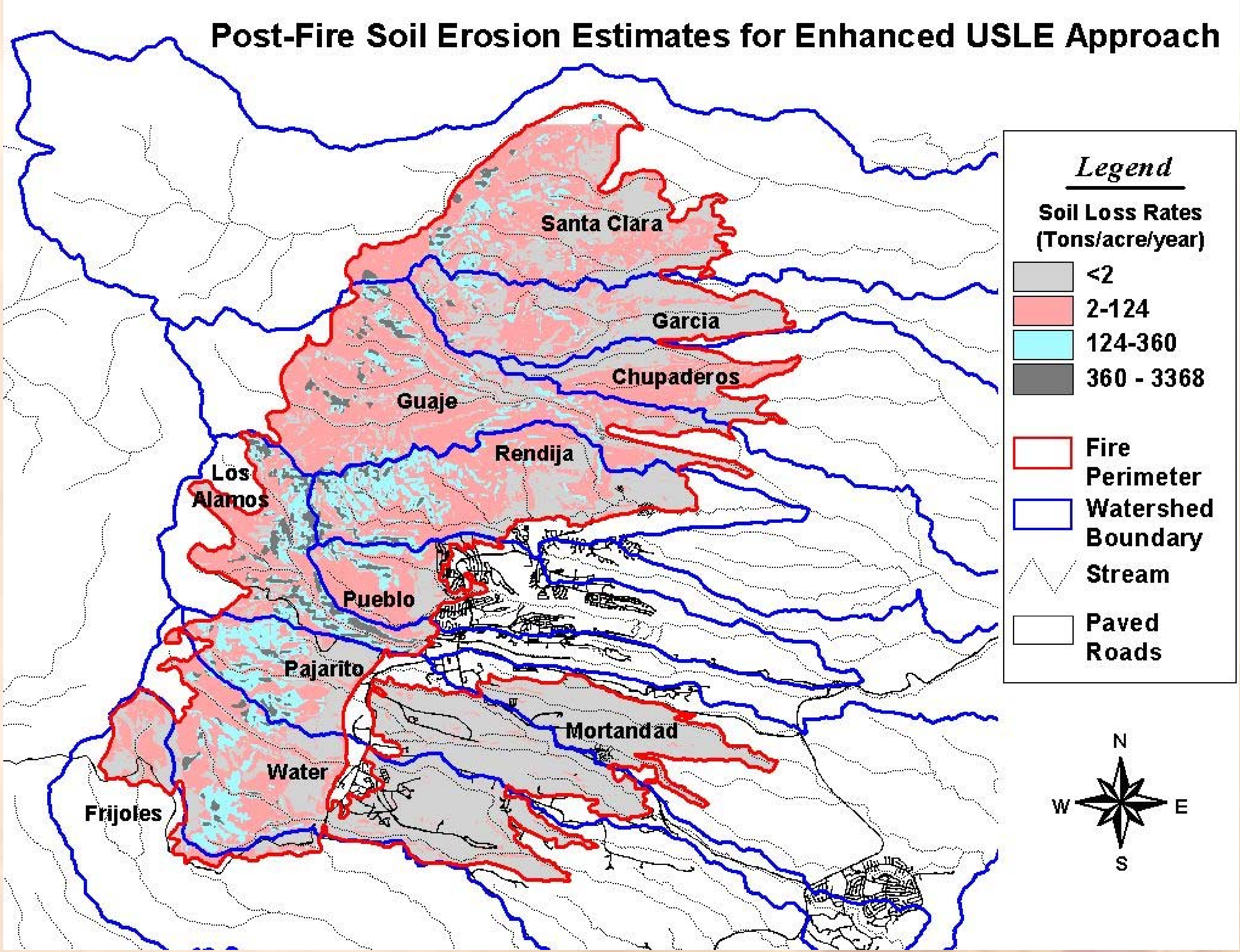

Figure 6. Predicted soil erosion after the Cerro Grande Fire.

Sensitivity Analysis

Manipulate

1. Fuel model (1, 2, 10 and 9)
2. Distance from shrub canopy to tree crowns (0.1 to 1.1 m)
3. Wind speed (8, 16 and 24 mph)

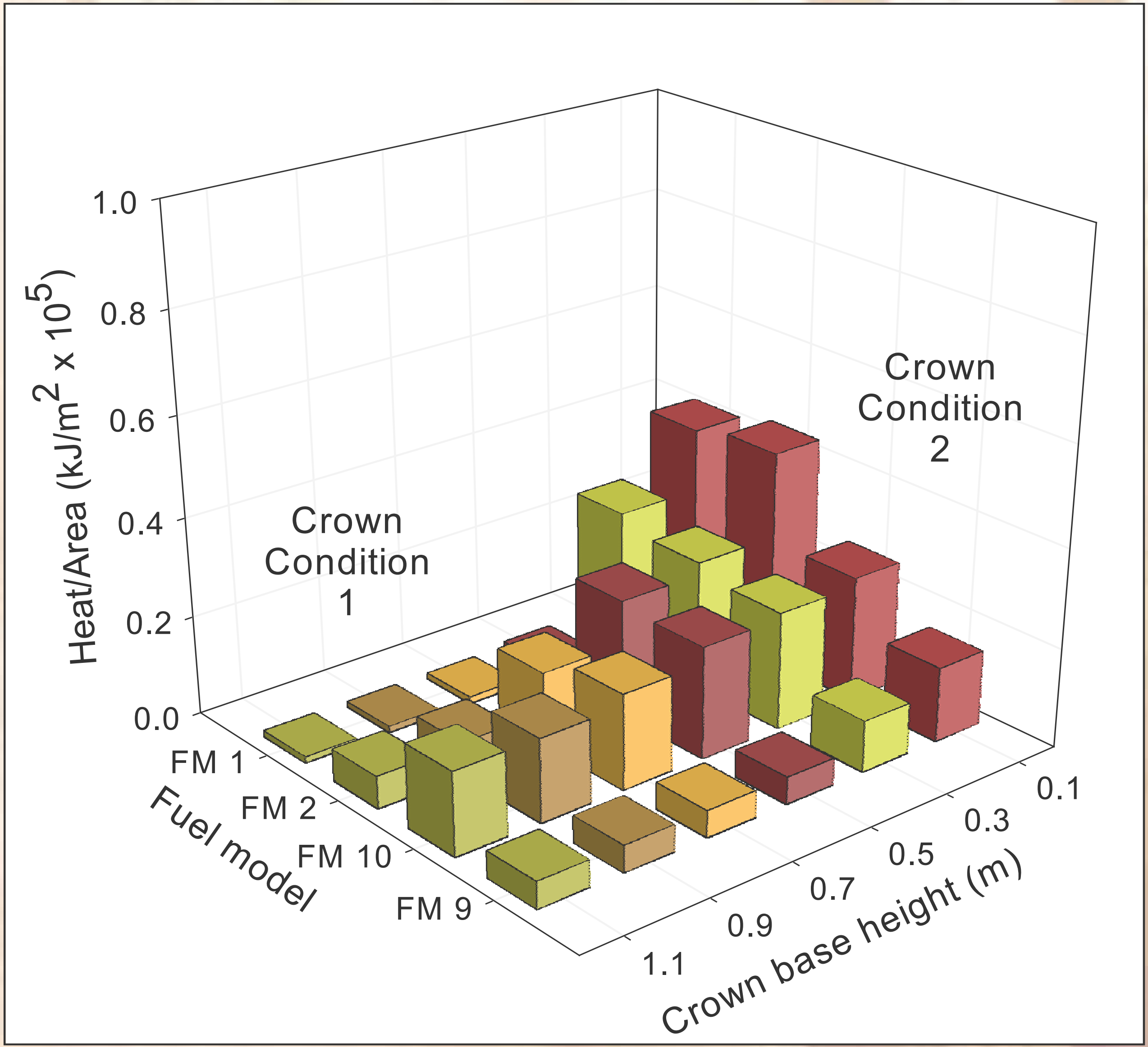

Figure 7. Model Output: Heat/Area, Wind Speed = 8 mph.

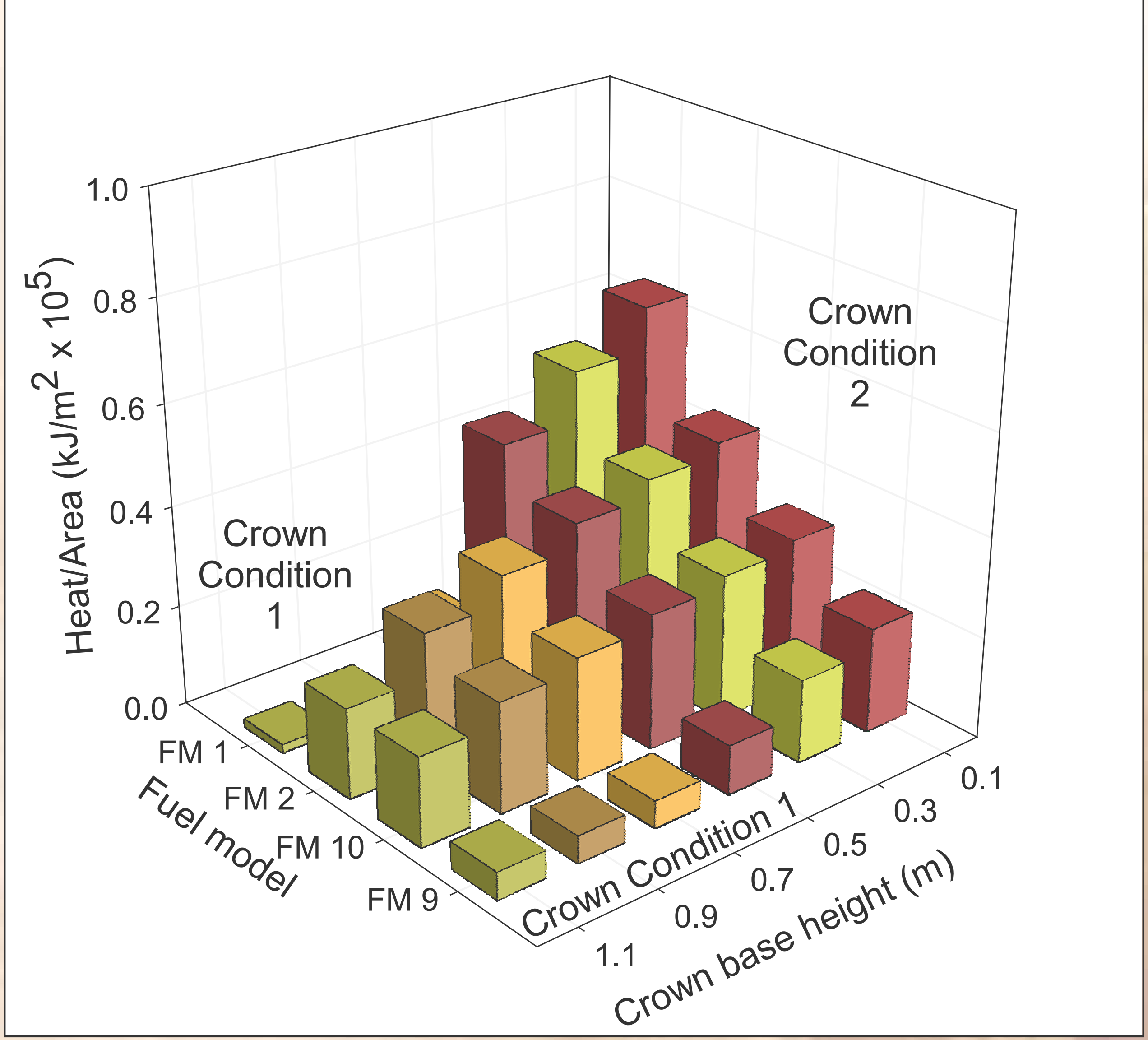

Figure 8. Model Output: Heat/Area, Wind Speed = 16 mph.

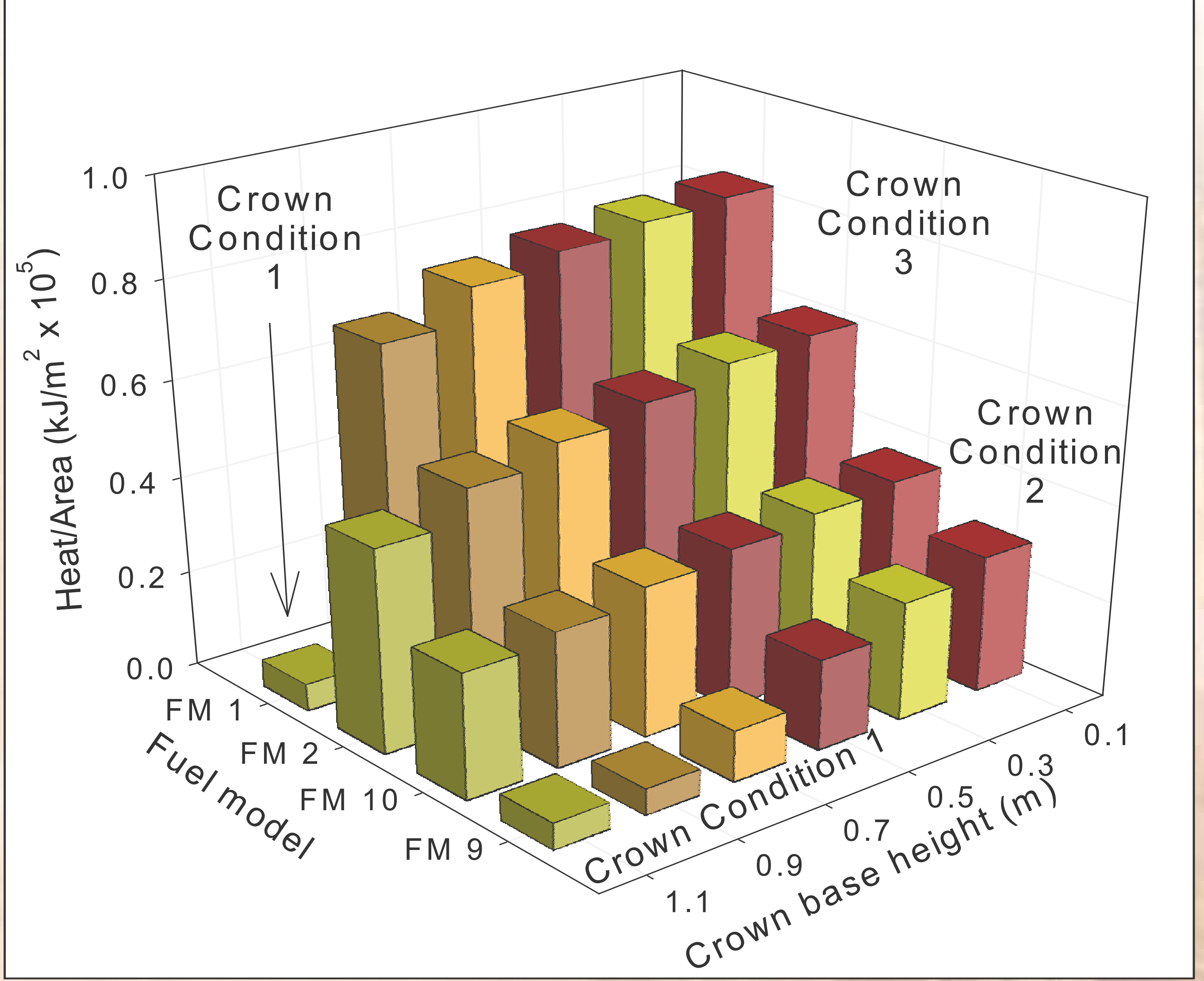

Figure 9. Model Output: Heat/Area, Wind Speed = 24 mph.

Validation against the Cerro Grande Fire

Manipulate the source of weather data (5/7/2000)

- Pajarito Mtn (10,364 ft) 2.1 miles from the fire
- TA-6 (7,424 ft) 4.3 miles from the fire
- TA-54 (6,549 ft) 9.9 miles from the fire

Figure 10. Fire progression and simulated fire (TA-54).

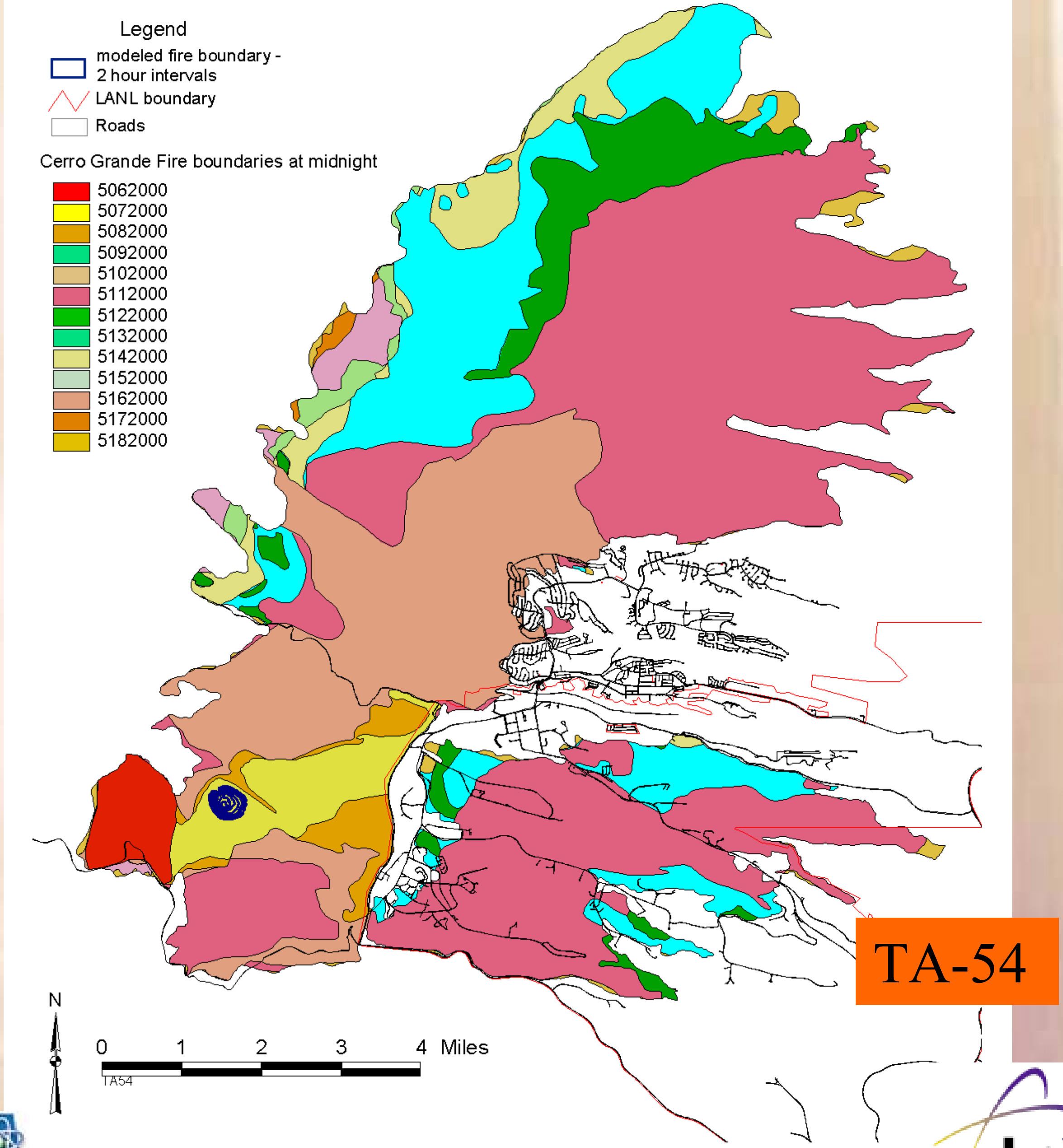

Figure 11. Fire progression and simulated fire (TA-6).

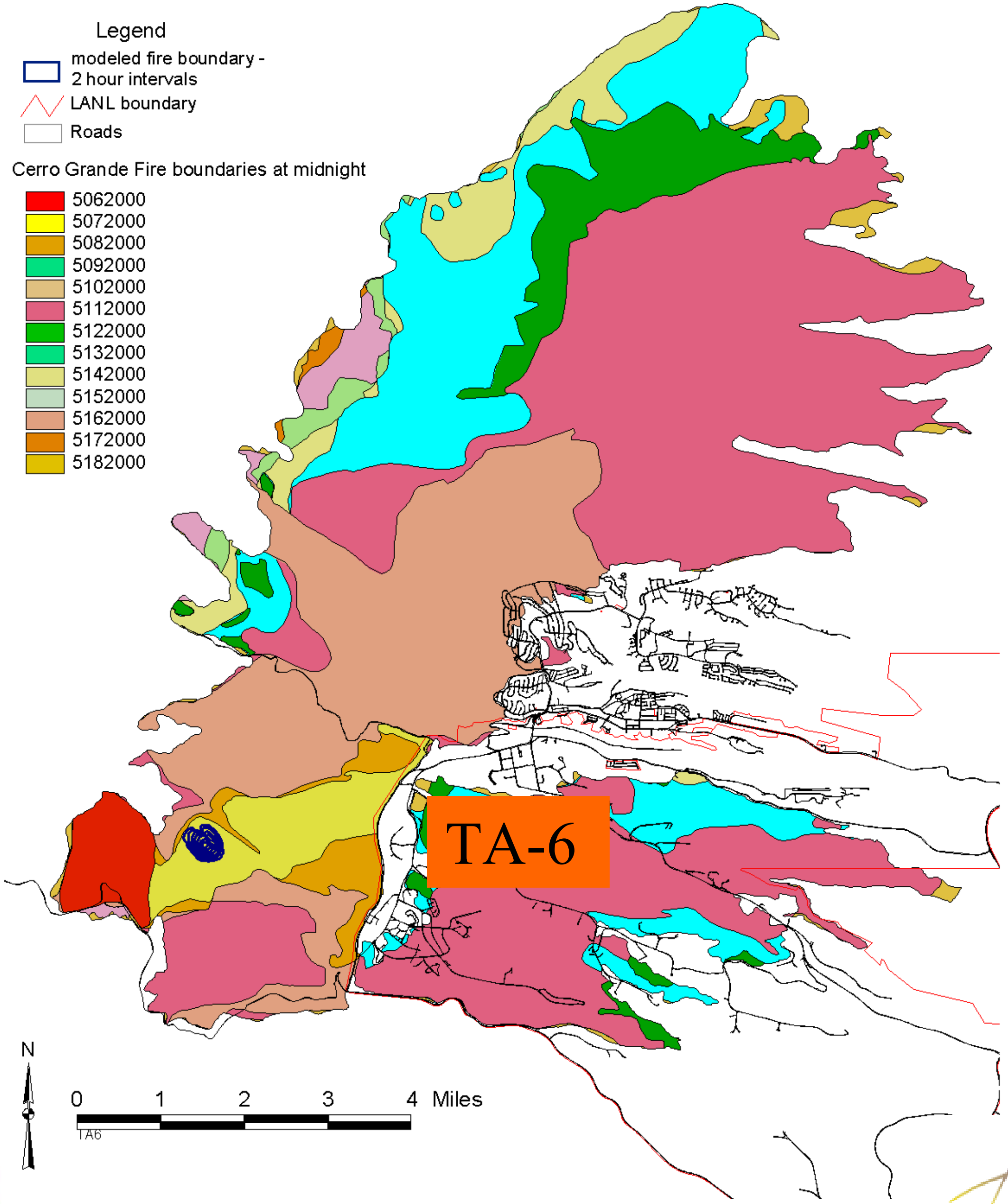

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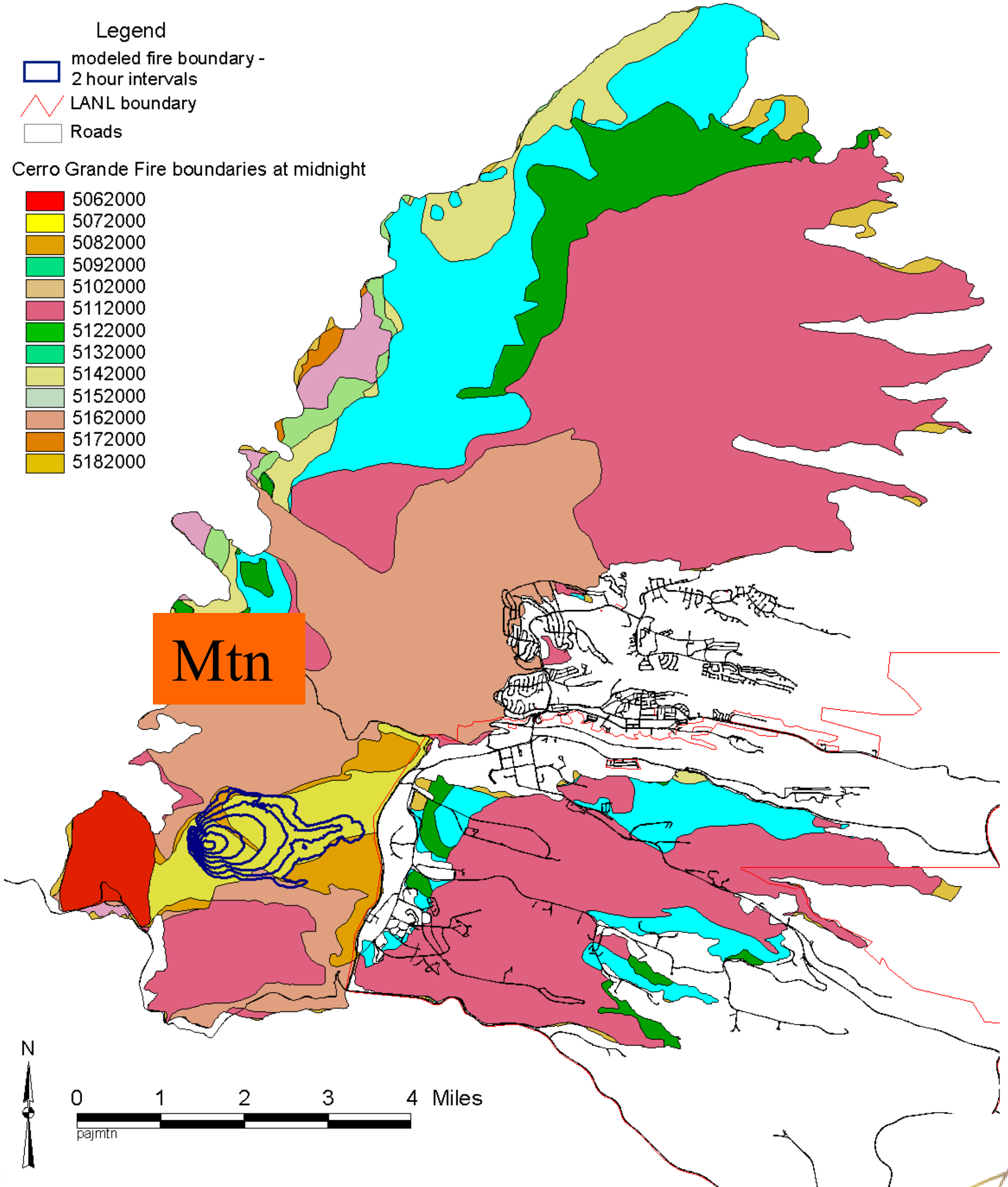
Figure 12. Fire progression and simulated fire (Pajarito Mtn).



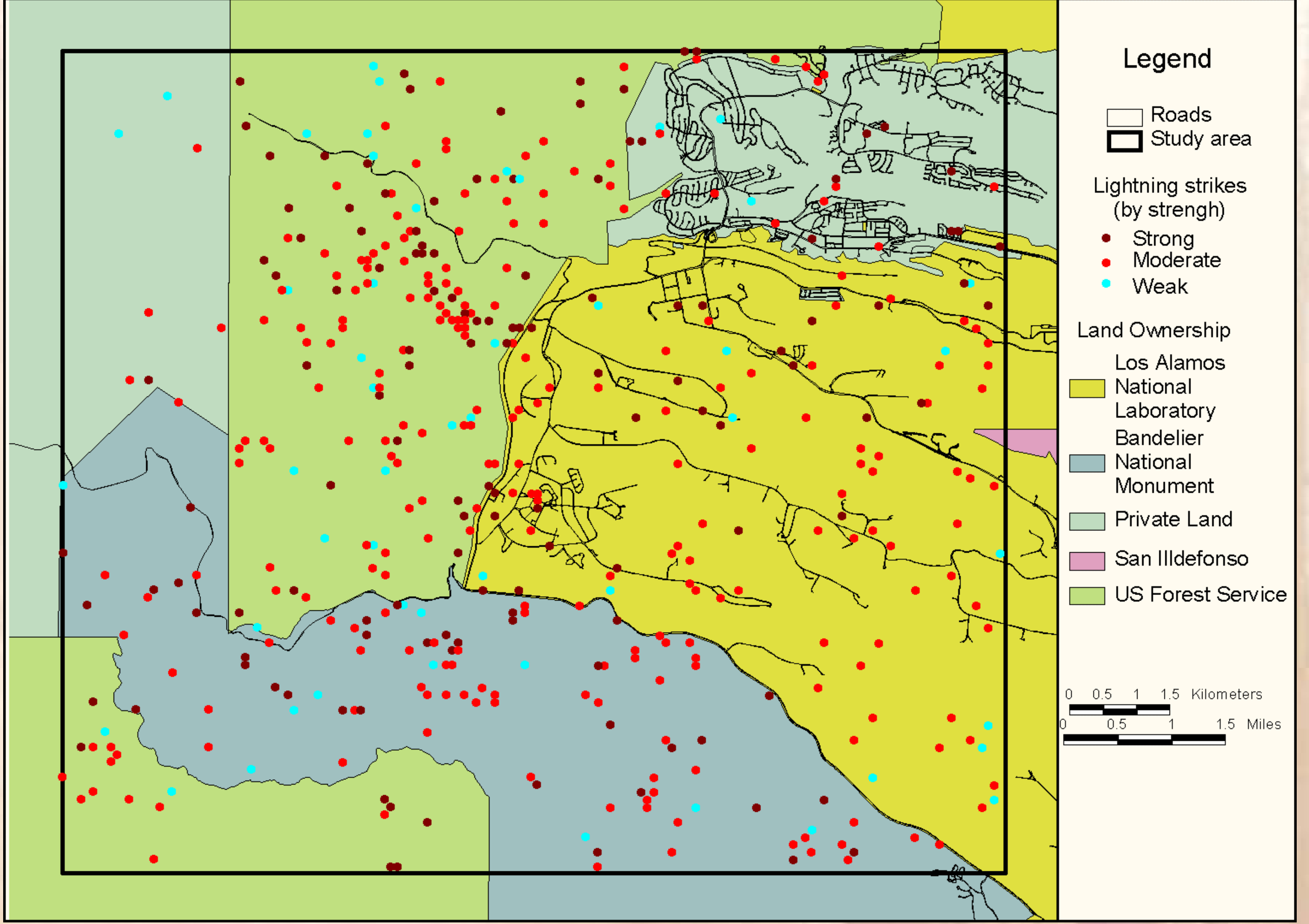


Figure 13. Lightning strikes for Monte Carlo simulations.

Average Expected Loss

$$AEL_{pre} = \tfrac{1}{N}\{\sum_{n\in N} S(n) + \sum_{n\in N}\sum_{x\in X} I_{n,x}[(F(x) + R(x)]\}$$

where

AEL_{pre} = the average expected loss to LANL from wildfire,

$S(n)$ = cost of suppression during the n^{th} wildfire,

$I_{n,x}$ = indicator variable of severe damage to facility x from wildfire n,

$F(x)$ = value of facility x excluding its contents, and

$R(x)$ = burdened costs LANL employees in facility x.

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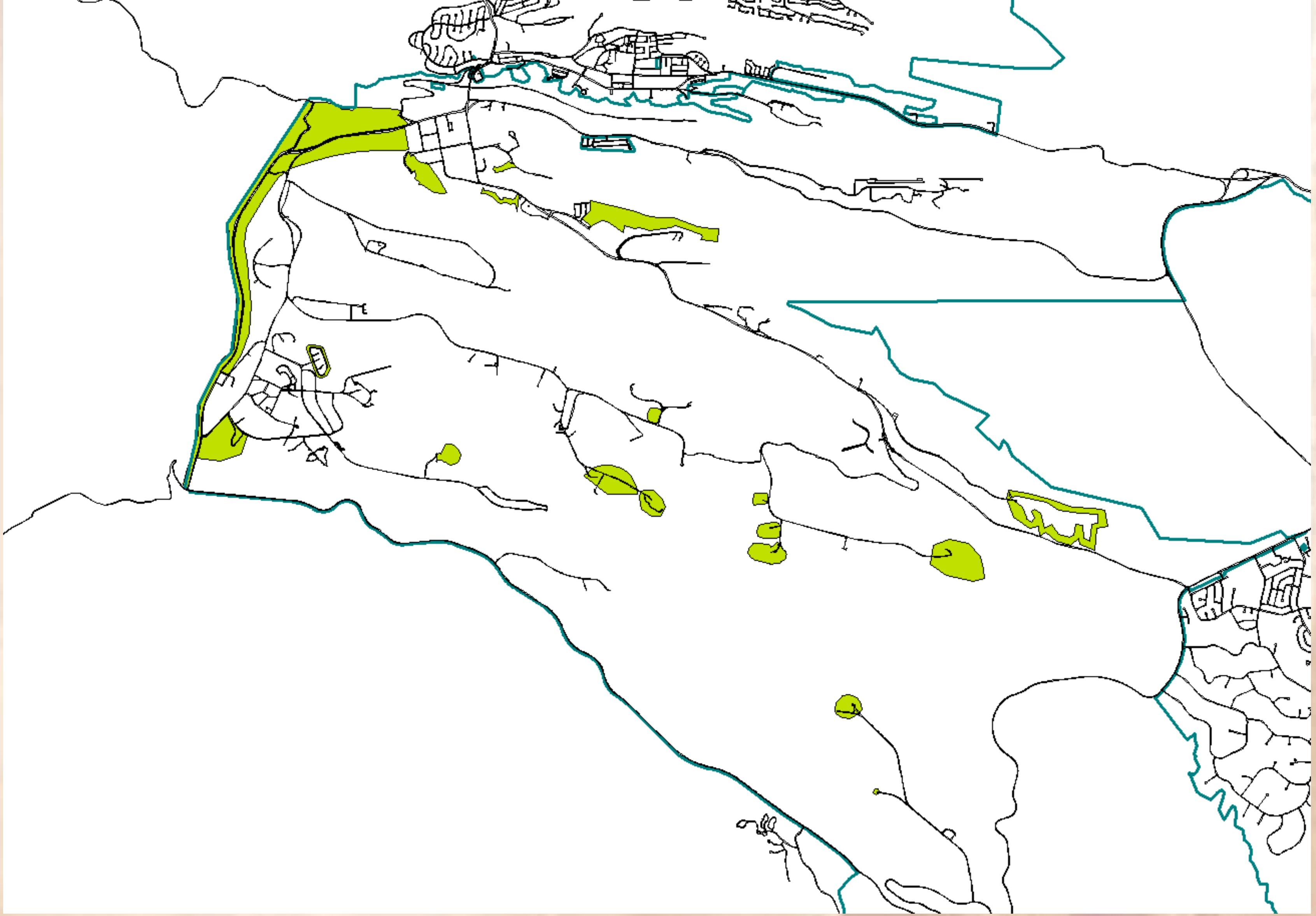

Figure 4. Thinning activities on the Laboratory (1997-2000).

Average Expected Loss

$$AEL_{post} = \tfrac{1}{N}\{\sum_{n\in N} S(n) + \sum_{n\in N}\sum_{x\in X} I_{n,x}[(F(x)+R(x)]\}$$

where

AEL_{post} = the average expected loss after thinning,

$S(n)$ = cost of wildfire suppression during the n^{th} wildfire,

$I_{n,x}$ = indicator variable of severe damage to facility x from wildfire n,

$F(x)$ = value of facility x excluding its contents, and

$R(x)$ = burdened costs Laboratory employees in facility x.

Reduced Expected Loss

$$REL = AEL_{pre} - (AEL_{post} + C)$$

where

REL = the reduced expected loss from thinning,

AEL_{pre} = the pre-treatment AEL,

AEL_{post} = the post-treatment AEL, and

C = the cost of thinning forests to fuel breaks.

Table 1. Average per-fire results of simulations (*N* = 47).

Intermediate result	Pre-thinning	Post-thinning
Acreage of fires	1594	914
Number of buildings affected	69	31
Number of displaced employees	177	45

Table 2. Cost components of AEL_{pre} and AEL_{post} in \$M.

Component	Pre-thinning	Post-thinning
Fire Suppression (*S*)	$ 0.20	$ 0.11
Burned Buildings (*X*)	$74.92	$31.33
Income losses (*R*)	$ 3.54	$ 0.90
AEL	$78.66	$32.35

Reduced Expected Loss

***REL* = $78.66 M – ($32.35 M + $2.50 M) = $43.81 M**

Continuing Activities and Goals: Wildfire Science and Management at the Ecology Group

1. System of permanent plots includes 197 monitoring sites
2. Collaborations with internal and external scientific groups
3. Wildfire behavior modeling system installed in the EOC
4. Upgraded land cover classification, land cover map, growth and yield models (FVS), and other capabilities
5. Integrated Resources Management Plan and Biological Resources Management Plan

Conclusions

1. Responded to the threat of wildfire after the Dome Fire
2. Upgraded wildfire evaluation and management capabilities
3. Combined science and land management to reduce the wildfire threat
4. Result: The Laboratory is a more safe and natural resources are better protected than before